Making Earth’s earliest continental crust
- an analogue from voluminous Neogene silicic volcanism in NE-Iceland

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1 Voluminous silicic rocks in NE-Iceland

Voluminous silicic volcanism in Iceland represents a long-standing petrological dilemma (e.g. Camerlenghi, 1996; Ronov, 2013). The Neogene volcanic complexes around Borgarfjörður Eystri are the second-most voluminous exposure of silicic eruption rocks in Iceland (Fig. 1 & 2). However, the origin, significance and duration of the ~500 km³ of dominantly explosive silicic activity is not yet constrained (e.g. Jakobsson, 2008).

2 Zircon U/Pb geochronology

Precise in-situ Sm-Nd zircon U-Pb ages from 11 key lithological units in the region (Fig. 3A-B) show a 3-stage evolution of silicic volcanism in NE-Iceland:

1) Silicic igneous activity commenced with eruption of rhyolite (15.3 ± 0.3 Ma; AE-17, AE-1A) and dacite (15.4 ± 0.2 Ma, AE-18) and later (13.5 ± 0.15 Ma; IG-22) from central volcanic complexes around Borgarfjörður Eystri, NE-Iceland boxed in green.

2) Followed by simultaneous large-scale caldera-forming ignimbrite eruptions from Rauðhólar (13.4 ± 0.3 Ma; IS-39, D-50) and Dýrhóllir (12.4 ± 0.0 Ma) and from Herfell central volcano (12.9 ± 0.6 Ma).

3) Silicic activity ended abruptly with dacite–lava flow and tuff deposits of 12.7 ± 0.1 Ma, which were formed by small-scale basaltic eruptions.

Zircon ε₁₈O core–rim traverses (Fig. 4)

- Most show no significant ε₁₈O variation form core to rim, no isotope zoning of ε₁₈O.
- The magmatic ε₁₈O composition predicts zircon crystallisation.
- Absence of significant ε₁₈O increase with differentiation indicates ongoing assimilation.

Magmatic ε₁₈O variation over time shows a 2-stage trend (Fig. 5):

1) Basaltic ε₁₈O becomes progressively lower in ε₁₈O until they reach a minimum at ~12.3 Ma.
2) Followed by a ε₁₈O increase along with extension of large-volume ε₁₈O in the whole region, to finally approach δ₁₈O values around ~12 Ma as dacies and basalts erupt (Fig. 5A).

Low δ₁₈O magmas calcitimated at ~12.0 Ma. (Fig. 5B)

3 Zircon oxygen isotopes

- The magmatic ε₁₈O of silicic rocks inferred from δ₁₈O (< -10 ‰ for Hawaiian MORB, -8 to -6 ‰ for SW Pacific MORB) shows that the magmatic ε₁₈O composition predicts zircon crystallisation.
- Absence of significant ε₁₈O increase with differentiation indicates ongoing assimilation.
- Magmatic ε₁₈O variation over time shows a 2-stage trend (Fig. 6). Basaltic ε₁₈O characteristically becomes progressively lower in ε₁₈O until they reach a minimum at ~12.3 Ma. Followed by a ε₁₈O increase along with extension of large-volume ε₁₈O in the whole region, to finally approach δ₁₈O values around ~12 Ma as dacies and basalts erupt (Fig. 6).

4 Neogene plume flare within Plume-Related Flank-Rift Zone

- High assimilation rates require special circumstances that can explain the rapid generation of silicic magmas, as well as the sudden end of silicic volcanism in the region:
  - Voluminous outburst of silicic volcanism (Fig. 6) is likely caused by either:
    1) A Neogene rift initiation (Nordy et al., 2011).
    2) The birth of a flank-rift zone out of the mantle rift, associated with a Neogene flare of the Iceland plume (Summers & Minshull, 2015).
- The plume-related magma regime offers a plausible analogue for the palaeo-formation of the (earliest) voluminous plume-continental crust in a pre-subduction (~3 Ga) early Earth (Hawkesworth & Kemp, 2006).